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A N  
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O N  
R E S P I R A T I O N :

B E I N G  
*An APPLICATION of the PRINCIPLES of the*  
NEW CHEMISTRY *to that FUNCTION.*

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SUBMITTED TO THE PUBLIC EXAMINATION  
OF THE  
FACULTY OF PHYSIC,  
UNDER THE AUTHORITY OF THE  
TRUSTEES OF COLUMBIA COLLEGE  
IN THE  
STATE OF NEW-YORK :

WILLIAM SAMUEL JOHNSON, LL.D. President;

FOR THE DEGREE OF  
D O C T O R O F P H Y S I C ;

ON THE THIRTIETH DAY OF APRIL, 1793.

---

BY JOSEPH YOULE,

Citizen of the State of New-York.

---

Hominem autem Jova Deus quum ex terræ pulvere formavisset, et in ejus  
nares spiritum vitalem inspiravisset, ex quo esset animans homo effec-  
tus.

GEN.

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William Pitt Smith.

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T O  
JOSEPH YOUNG,  
PHYSICIAN;

A N D  
WILLIAM PITT SMITH,  
PROFESSOR OF MATERIA MEDICA  
IN COLUMBIA COLLEGE:

*INDEBTED to you for the foundation  
of the small Medical Superstructure, which, through  
PROVIDENCE, I have been enabled to erect—having  
piloted my little Bark to the Haven of her Desire; if  
any thing in the following pages shall be found worthy  
of attention,*

PERMIT *them to be* DEDICATED to you,

*With every mark of* ESTEEM and RESPECT,

*By your* FRIEND and PUPIL,

The AUTHOR.

TO  
SAMUEL BARD, M. D.

PROFESSOR OF CLINICAL MEDICINE,

AND

DEAN OF THE MEDICAL FACULTY:

THIS

DISSERTATION

Is inscribed,

As a mark of respect.

APPLICATION *of the* PRINCIPLES

OF THE

NEW CHEMISTRY *to* RESPIRATION.

**T**O live and to breathe are synonymous expressions. Respiration is, therefore, a function of the animal body, with propriety termed *vital*. It would be a pleasing, as well as profitable undertaking, to trace the progress of the human mind in the investigation of this phenomenon of being. Notwithstanding it has engaged the attention of Physicians and Philosophers of every age, nothing has been written on the subject, till within a few years, which is worthy of attention. The rapid improvements in the science of *Aerology*, of which Doctor PRIESTLY is the discoverer, have enabled the *moderns* to view the subject in a more just manner than the *ancients* could possibly have done.

Air is necessary to the existence of all organized beings. We find none existing where they are not admitted to its contact; even plants, as well as animals, are found by experiment to die *in vacuo*.

Nature

Nature has taken great pains to provide animals, even of the most insignificant kind, with organs for bringing their blood sufficiently in contact with the fluid in which they live. This is instanced in a manner remarkably curious in insects, in their different modes of existence. From numerous observations it appears, that air is more essential to animal life than aliment. It forms a great part of the food of plants, and probably also of animals; but each of those classes of being requires it of different kinds: that which is the most salubrious to plants being noxious to animals; and that which is emitted as excrementitious by the former, most salutary to the latter. Thus, by an unequalled design, are those two kingdoms made to labour for each other, and the balance between the components of our atmosphere preserved.—The death of animals, by submersion, strangulation, and suffocation, is produced by a privation of this all-vivifying fluid. We may be easily convinced of its essentiality to life, by voluntarily suspending respiration a few moments.

The vast ærial ocean in which we continually move, although apparently a simple fluid, is in fact a very heterogeneous mass. It is composed of the various substances which are capable of being volatilized at the temperature at which it exists, and which it can by its solvent power suspend. Mons. LAVOISIER has proved, synthetically and analytically, that it is composed of *oxigenous gas*, and *mephetic airs*, in the proportions of 27 and 73 to the 100 parts.

This

This *mephetis* consists chiefly of *azotic*, although it contains a small portion of *carbonic* and *hydrogenous gases*.\*

That *carbonic gas* enters as an ingredient in the composition of our atmosphere, has been proved to a demonstration. It is sufficient for this purpose to mention, that lime water exposed to the air is rendered turbid, the lime becoming precipitated; and that caustic alkalies (pure alkalies) are *carbonated*, or rendered effervescent.

That *hydrogenous gas* exists in the atmosphere, has not so generally been allowed: but whoever will consider what a vast quantity of this gas is exhaled from marshes, mines, putrifying animal and vegetable substances, will not have a doubt remaining on this head.

The airs, then, which compose our atmosphere, are, the *oxigenous*, *azotic*, *carbonic*, and *hydrogenous*.†  
Now,

\* The *oxigenous*, *azotic*, *carbonic*, and *hydrogenous gases* of the French Chemists, are synonymous with the *dephlogisticated*, *phlogisticated*, *fixed*, and *inflammable airs* of PRIESTLY.

† The mechanical properties of the atmosphere have, till very lately, entirely attracted the notice of Philosophers. The attention of men of the greatest eminence is now turned towards its composition. The proportions of the ingredients in this fluid must vary according to a variety of circumstances and situations. The analysis of the accurate LAVOISIER, already mentioned, is about the medium, and may be most relied upon, as his abilities and apparatus enable him to do justice to the inquiry. The proportion of *carbonic gas* is generally estimated at an hundredth part, that of the *hydrogenous* is not ascertained. Probably neither are essential to the composition of atmospheric air, as the *azotic gas* is sufficient to qualify the action of the *oxigenous*.



Now, as animals cannot live without air, it must be some one of these components of the atmosphere in particular, which supports their existence, or the whole collectively.

*Azotic gas* (as its name signifies) is noxious to animal life. “It cannot be breathed by animals, neither will it admit of the combustion of inflammable bodies, nor of the calcination of metals.” If common air be inspired into the lungs, and again expired into a receiver, the volume becomes diminished, while the *azotic gas* remains the same both in quantity and quality. It is, therefore, unfit for the purposes of respiration. Hereafter it will appear, that respiration is not merely a passive function; that it is not confined to the mere reception and emission of air.

The unrespirability of *carbonic gas* was long since shewn by VAN HELMONT, and has since been proved by HALES, PRIESTLY, and others. It is manifested by the experiments which have been made on dogs in the *grotto del cano*, and by accidents which happen in breweries, cellars, and places where the process of fermentation is going on. It is this gas which produces the fatal effects that follow from the combustion of charcoal in confined places. The experiments which have been made on animals in the air exhaling from mineral waters, prove the same fact. It is further corroborated by the actual experiments of the Abbé NOLLET, and the intrepid PILATRE DE ROSIER,

ROSIER, who breathed it at the hazard of life: DE ROSIER had not taken more than two or three inspirations, before he was seized with all the symptoms of apoplexy. BERGMAN observes, that it kills animals instantaneously, and that the hearts of animals so destroyed are entirely deprived of their irritability.

*Hydrogenous gas* is likewise incapable of supporting respiration. "Birds, placed successively in a vessel filled with this air, died without producing the smallest perceptible change in it." M. CHAPTAL says, that he respired it himself, and found that the same air might be taken into the lungs several times without danger; and that it was not in the least vitiated or diminished after the experiment. DE ROSIER likewise inspired it several times with impunity. From these facts it appears that *hydrogenous gas* is incapable of being decomposed in the lungs: It is then merely a passive substance in respiration, producing death by a negation of some other principle which can support this process.\*

Having ascertained that neither *azotic*, *carbonic*, nor *hydrogenous gas* can support respiration, it therefore follows, that the *oxygenous* is the only one fit for  
B
this

\* From the experiments of several eminent persons on this gas, it would appear, that it exerts a positive operation in the lungs, and that it is in itself deleterious. The Abbé FONTANA found extreme difficulty in taking three inspirations of it. These apparent contradictions will reconcile themselves when we consider the power which this gas possesses of dissolving charcoal, sulphur, phosphorus, and several of the metals.—One positive experiment, like those mentioned in the text, ought to have more weight than an hundred negative ones.



this purpose; for the existence of any other in our atmosphere is not ascertained.

This gas, like every other, is a compound substance. It is formed of a radicle or base, called *oxigene*, held in solution by *caloric* (*heat, fire, igneous fluid, matter of heat*) to the point of saturation, which constitutes its principle of elasticity.

From the numerous experiments which have been made, it appears that *oxigenous gas* is capable of supporting respiration only a certain time; and that air is respirable in proportion to the quantity of this gas contained in it. Count Morozzo placed ten sparrows successively under a glass filled with oxigenous gas; the first died in five hours and twenty-three minutes, and the air became considerably diminished in quantity; the second died in two hours and ten minutes, the third in less time, and so on; the duration of their existence diminishing in proportion to the diminution and vitiation of the air. Others, that were placed in atmospherical air, died much sooner than those in oxigenous gas; the collective duration of the existence of three sparrows placed successively in the latter, being three times greater than in the former; corresponding with the proportion of oxigenous gas present. CHAPTAL says, that air in which five sparrows had died, yielded only seventeen hundredths of vital air.—As we have shewn, that none of the gaseous parts of the atmosphere are capable of supporting respiration  
except

except the oxygenous, it must be from a diminution of this that breathing becomes difficult in crowded assemblies without free ventilation.

The above cited experiments shew that air is diminished by animal respiration. The loss in one hour, by the breathing of a man, is 360\* cubic inches, which will contain, according to the experiments of LAVOISIER, 130 grains of solid oxygen. Now, it is impossible for this gas to be diminished in bulk, unless by cold or by pressure, without decomposition; and in order that such decomposition may take place, it is necessary that some substance should come in contact with it, for which its oxygen has a stronger attraction than it has for its caloric: Such a substance exists in the lungs of animals, and shall be pointed out in its proper place.

As oxygenous gas is decomposed in the lungs, respiration may be considered properly a species of oxygenation. Accordingly, it is found that the same changes take place in the air during calcination, combustion, and fermentation, as in respiration. These processes require similar circumstances to favour them, and produce several phenomena common to each. 1. Oxygenous gas is required. 2. Caloric is disengaged. 3. Oxygen becomes fixed. 4. The

\* " M. DE LA METHERIE has proved that 360 cubic inches of vital air are absorbed in an hour. My experiments have not shewn so great a loss." CHAPTAL'S CHEMISTRY.

The estimate of the loss of air in an hour by HALES, is the same as that of LA METHERIE. See his Staticks.

4. The augmentation of the weight of the products is equal to the weight of oxygenous gas employed.

If respiration is a species of oxygenation or combustion, why does not the disengaged caloric manifest itself in the form of light and flame? The reason is readily assigned.—The process of oxygenation varies according to a variety of circumstances. In order that it may go on in a rapid manner, it is necessary that the substance to which the oxygen is attached should have a strong attraction for it, and that it should be in a temperature most favourable to such an attraction. It is likewise necessary that it should be concentrated, and not diffused through a mass of incombustible matter. There is but one of those favourable circumstances existing in the lungs of animals: the substance by which oxygen is attracted there, has indeed a strong affinity for it, as shall be shewn; but it is diffused through a fluid unsusceptible of combustion. The temperature of animal bodies is probably not the most favourable to a rapid process. The disengaged caloric will, under these circumstances, consequently, be invisible, a sufficient quantity not being evolved in any given space of time to manifest itself by the properties of flame and light. Moreover, as soon as the caloric is let loose in the lungs, it is communicated to the formation of the vapour and carbonic acid gas which are continually exhaling from the lungs.\*

As

\* Whether the vapour exhaling from the lungs of animals is formed there, by the union of hydrogen passing from the blood with the oxygen

As the diminution of *oxigenous gas* by animal respiration is constant and successive, we must look for some substance in the lungs to which its base becomes attached. We know of no other matter there which has an attraction for *oxigene* sufficient to disengage it from its *caloric*, except the *blood*. In respiration, therefore, the solid matter of oxigenous gas must unite with this fluid. I am of opinion, that the oxigene of all the gas which is decomposed in the lungs passes into the blood.

### The

from the air, or whether it be a fluid exhaled from vessels already formed, is doubtful. The latter conjecture I think the most probable; for CHAPTAL says, that when hydrogenous gas is taken into the lungs of animals repeatedly, it does not alter either its quantity or quality: If hydrogen is constantly exhaling from the blood, ought not the volume of gas to have been augmented?—I intend hereafter to determine this point, by placing animals in hydrogenous gas; if this aqueous fluid is then exhaled, it must be secreted from the blood. From a cat which I saw Professor KEMP place in a tolerably good vacuum, this halitus was exhaled, and manifested itself by condensing upon the sides of the receiver.—This fluid appears to possess the properties of water, and must therefore be formed in the exhalant arteries; for I do not know of a drop of water, *QUA AQUA*, in the animal body. It is transparent, almost tasteless, and evaporates by heat without coagulation or leaving any residuum.

That carbonic acid gas exists in greater quantity in the air expired from the lungs of animals than it did previous to inspiration, is proved by its rendering lime-water turbid, reddening the tincture of turnsole, and by carbonating alkalies when caused to pass through them. See GOODWYN'S inaug. dissert. PRIESTLY on air. CHAPTAL'S Chem.—I am inclined to believe that the compound radicle of this gas is formed in the blood, and not in the vesicles of the lungs; for, “according to the experiments of the Count DE MILLY, and the observations of FOUQUET,” carbonic gas is constantly passing off from the skin as well as the lungs. If “air be placed in contact with blood, it acquires the property of precipitating lime-water.”

Whether the aqueous matter and carbonic acid are formed in the lungs or not, they require a large quantity of caloric to convert them into the gaseous state; and must, no doubt, take up all the caloric which is extricated from the oxigenous gas in the lungs.



The decomposition of such a quantity of *oxigenous gas* as takes place in respiration, must produce some corresponding change in the blood; for experiments shew that this substance is a very general and powerful agent in nature. It was long since observed by LOWER, that the blood which flowed from the pulmonary veins was more florid than that which flowed from the artery. The same fact has been since taken notice of by BOERHAAVE, HALLER, CIGNA, HEWSON, GOODWYN, &c. &c. The blood, then, acquires a more florid appearance during its passage through the lungs.

The cause of this florid appearance has been made the subject of the prize questions of many learned societies. It was a long time attributed to *nitre* in the air, from the property which this substance has of communicating a red colour to blood out of the body. BOERHAAVE attributes it to texture; HALLER to a mixture of *oily* and *ferruginous matter*; HALES to *sulphur*; HEWSON to the efficacy of the *spleen* and *lymphatic glands*! The fact is, there have been as many conjectures respecting the cause of it, as there have authors written on the subject.—It was left for the immortal PRIESTLY to prove that the blood is indebted to what he calls *dephlogisticated air* for its red colour.\*

He

\* The Doctor does not appear to have had an idea of the decomposition of this gas in respiration; he supposes it most fit for this purpose of any of the airs, because "it contains the least phlogiston;" and therefore, according to his idea, it is the best solvent or menstruum for that principle. Hence, says he, respiration is a "phlogistic process, the use of the lungs

He exposed a quantity of venal blood to common air, and found that by agitation it immediately became red; but this was more eminently the case when oxygenous gas was used, and in a shorter time.\* Blood rendered florid in this manner, and blood taken from an animal in this state, were exposed to *hydrogenous, azotic and carbonic gases*; the florid colour immediately disappeared, and the blood became black; but upon exposure to *oxygenous gas*, it soon resumed its former appearance. Blood becomes red in proportion to the quantity of oxygenous gas contained in the air to which it is exposed.

HEWSON

being to discharge that phlogiston which had been taken into the system with the aliment." But as all the phænomena which the Stahlians ascribe to the disengagement of phlogiston, are produced by combinations with oxygen, the experiments of Dr. P. are equally applicable to our purpose, as if they were made upon the principles of the French Chemistry.

\* Here it will be pertinent to remark, that as blood is rendered fluid sooner, and in a greater degree out of the body, by exposure to oxygenous gas than to atmospherical air, it is certainly preferable, in cases of suspended animation, to inflate the lungs with it. GOODWYN found by using this instead of common air that he could restore animals sooner. This gas I conceive, might be exhibited with great advantage in fevers of the typhoid kind, in dropsies, chlorosis, and other diseases of debility. It is easily procured, and is not a very dear remedy, as 1200 cubic inches can be obtained from one pound of nitre; and one pint from an ounce of minium. It is a grand desideratum to find a mode for obtaining it from water. Mint, lavender, and many other fragrant plants emit it in copious quantities, and might be placed in a sick room with great advantage; they would be pleasing to the eye, grateful to the smell, afford a stimulus to the heart, and would absorb the unrespirable part of the air. CHAPTAL relates a case or two of its beneficial influence in pthisis pulmon. The breathing of this air "diffuses an agreeable warmth in the breast, inspires cheerfulness, renders the patient happy:—In desperate cases, it must certainly be a precious remedy which can spread flowers on the borders of the tomb, and prepare us in the gentlest manner for the last dreadful effort of nature.

HEWSON says, that he injected air into a vein between two ligatures, and found that the contained blood assumed a more florid appearance. BECCARIA exposed blood in vacuo; it immediately became black. PRIESTLY says, that he repeated the experiment with the same result.

The blood does not come in actual contact with the air in the lungs. That oxygenous gas can act through membranes apparently more dense and impermeable to air than the vesicles of the lungs, is evident from the following experiment of Doctor PRIESTLY. A quantity of black blood was inclosed in a bladder, and exposed to the air; when it was examined, it exhibited the same florid appearance as if it had been in actual contact with that fluid, the bladder appearing to be no obstruction to the process of *floridation*.

It is a curious and interesting fact, that oxygenous gas can act on blood although it be covered with a stratum of serum of the depth of two inches and an half: whereas the slightest covering of oil, saliva, or water, effectually prevents its action.

As florid blood becomes black in vacuo, or when exposed to any of the unrespirable gases; as this colour is restored by exposing it to oxygenous gas, which at the same time becomes diminished; as blood is changed from black to red by oxygen out of the body, whether it be imparted to it from acids, neutral salts, oxygenous gas, or gases containing a  
portion



portion of this; we may safely conclude, that this principle is the immediate cause of the same change which the blood undergoes in the lungs.

PRIESTLY found by experiment, that if successive quantities of florid blood were placed in contact with a quantity of hydrogenous or azotic gases, they became in a degree respirable, and that nitrous air became lessened in bulk, at the same time losing its power of diminishing oxygenous gas.—These phenomena, according to his theory, he ascribes to the absorption of *phlogiston*, by the blood, from the air: but any person versed in the doctrines of the NEW CHEMISTRY will perceive, that they are owing to an emission of oxygenous gas, the base of which exists in the blood.—This view of the subject affords an easy and satisfactory answer to the unphilosophical question, whether air exists in the blood in an elastic form? That the base of air exists in the blood, and that it will easily assume the gaseous state, is evinced from the experiments just mentioned; but if a vein be taken out of an animal with a ligature passed round each end, and it be placed under an exhausted receiver, it will not swell; or if an artery or vein is punctured under water, not even the smallest bubble of air ascends. If air was to be injected into the veins of an animal, it would destroy its life; for we must be convinced from the analogy of the blood vessels to hydraulic tubes, that a small quantity of air in any of their superior flexures would effectually obstruct the circulation of the blood.

The blood of *fishes*, of the *fœtus in utero*, and of the *chick in ovo*, is red. Are not these objections to the theory which supposes that *oxigene* is the *floridifying principle* of blood?

That *aquatic animals* require air for the continuance of their existence as well as the *terrene*, is rendered sufficiently evident from the well known fact, that fish in the winter will rush in crowds to holes which form or are formed in the ice—an artifice frequently used for taking those animals. This position is further corroborated by the following experiments. If a few fishes are placed in a vessel of water, and the air be effectually excluded, they will soon die. The same takes place in vacuo.

These creatures seem to suffer the same inconvenience from being crowded together in a small quantity of water, as men or other land animals do, when in confined places—the water probably not being sufficiently permeable to air to afford them necessary supplies.

The experiments of PRIESTLY throw great light on this part of our subject, and furnish sufficient data to prove, that *oxigene* is necessary to the floridification of the blood of fishes.—He inclosed a number of these animals in different vessels, containing water, with atmospheres of nitrous, hydrogenous, azotic and carbonic gases; under which circumstances they died in a short time—in the carbonic gas they expired convulsed. He likewise placed two small  
fishes

fishes in a pail of water: after they had been in twenty-four hours, he found that the water had lost its property of purifying air. In repeating the experiment with water which contained air of great purity, he found, after the fish had died in it, that the air which it contained had not only become diminished in quantity, but also that its quality was worse than that in which a candle goes out.

From these experiments it appears, that the gases which are noxious to land animals, are unfit for the respiration of fishes. From the diminution of the quantity of pure air in the water in which these animals had been, it is evident that they decompose oxygenous gas, and that, like terrene animals, they want constant supplies of fresh air.

With respect to the young of animals *in utero*, it is now rendered sufficiently evident, that they are supplied with arterial (oxygenated) blood by the umbilical vein.—Whether the vessels of the placenta have a power of taking up chiefly that part of the blood in which oxigene resides, or whether the arteries of the uterus transmit to the veins of the placenta chiefly that part, is doubtful. Probably this will not appear necessary when we advert to the well ascertained fact, that the blood of women during pregnancy, and probably of other animals, manifests a highly florid colour.—So wisely has Nature adapted means to ends, and upon such beautiful principles has she constituted the animal œconomy, that the  
irritability

irritability and tone communicated to the system by a distention of the uterus, should act as a physical cause in increasing the power of oxygenating blood, in order that the fœtus may be supplied without injuring the mother.

“ The gen’ral ORDER since the whole began,  
“ Is kept in NATURE, and is kept in MAN.”

That *oxygenation* is necessary to the blood of the *chick in ovo*, is manifested from the fact, that if the communication between the membranous lining of an egg-shell and the external air be cut off, it is incapable of being hatched. If I had time sufficient for the purpose before me, I would try if it was possible to hatch chickens in any of the unrespirable airs, and whether oxygenous gas would facilitate that process. That their shells are permeable to oxygenous gas, may be inferred from the putrefaction of eggs. When animal substances putrify, carbonic acid gas is exhaled; and from analogy I conclude this to be the case with them. Oxigene is essential to the formation of carbonic acid, and if it could not penetrate their shells, it is probable that they would never putrify. It is a notorious fact, that if they are coated with, or immersed in any substance which will exclude the air from them, they may be preserved from putrefaction, even during the warmest seasons, for a long time. The membrane which lines the internal surface of the shells of eggs, is found to be turgid with blood in advanced incubation; probably it performs the office of oxygenation for the chick whose lungs are inactive.

Here



Here arises a curious and important question—*important*, because, if it could be satisfactorily answered, we should be in possession of a never-failing mean of increasing the energy of the sanguiferous system:—*To which of the component parts of the blood does the oxigene become united, and what is its nature and properties?*

The inferences drawn from the experiments of PRIESTLY and others, shew that oxigene is the *floridifying* principle of the blood; but what is the nature of that principle which is capable of being *floridified*, remains to be determined by experiment. 1. It must reside particularly in the colouring part of the blood. 2. It must be common to the blood of all red blooded animals. 3. It must have a great affinity for oxigene at a moderate temperature.

*Iron*, as a principle always present in red blood, seems to promise a happy explanation of this phenomenon. The arguments which present in favour of this being the floridifiable principle, are, 1. It is always present in the blood of animals. 2. It is found in the greatest quantity in the colouring\* part. 3. It has an universal agency in nature, “in colouring clays and stones from the darkest brown to the most beautiful red.” 4. The union of this substance with  
oxigene

\* The blood is here supposed distinguishable into three separate parts, serum, coagulable lymph, or fibrous portion, and colouring part.—According to the most accurate analysis of the blood, iron resides exclusively in the colouring part.

oxigene produces a colour fimilar to that of the blood.  
 5. It is a substance friendly to animal bodies, increafing the density, floridity, and circulation of the blood.  
 6. It is one of the moft combuftible of the metals, and eafily reduced to an oxide (calx) by oxigene.—  
 Does not the quantity of iron in blood accord with the degree of its floridity ?

These arguments do not appear fufficiently cogent to afford full fatisfaction. The attraction of iron for oxigene at the temperature of animals, is not fufficiently great to account for that instantaneous change which the blood undergoes in the lungs, or when expofed to oxigenous gas out of the body. The proportion of iron found in blood, does not appear fufficient to account for its florid appearance ; but when we confider how much colour depends upon texture, this objection will not militate fo ftrongly. A quantity of red oxide of iron, equal in weight to that which is obtained from a given weight of blood, will not diffufe that beautiful red appearance through fo large a mafs of water as the colouring matter from an equal quantity of blood. Red oxide\* of iron does not remain in folution, in water, like the colouring part of the blood. Upon the principles of this theory, iron fhould be a more certain

\* The oxides of iron differ in colour according to their degrees of oxigenation ; fome containing not more than from twenty to twenty-five parts of oxigene to the hundred ; while others have this principle in the proportion of thirty-two or thirty-four hundreths ; in which laft ftate they form a beautiful red, like carmine. FOURCROY, vol. i. p. 413.

certain remedy, always increasing the quantity of colouring matter, and consequently the floridity.\*

Upon the whole, the presence of iron in red blood is not sufficient to account for all the changes which take place in the lungs of animals. It is, therefore, necessary to call in the aid of some other of the component parts of the blood, by which we shall be able, either singly or conjunctly with iron, to account for them in a satisfactory manner.

*Phosphorus*, as another never-failing principle in the composition of red blood, will afford much assistance in the solution of this difficulty. The circumstances, which *a priori* appear in favour of this substance, are, 1. That it is always found in the blood of animals. 2. That its attraction for oxygen is very strong, and that at a *low temperature*. 3. Human

\* Chalybeates probably do not produce any great effect till they are taken into the circulating mass. They then form a base, or increase the power of some other substance existing in the blood for the attachment of oxygen in the lungs. The blood, being more highly oxygenated, will stimulate the extreme arteries of the system to greater action; and a greater quantity of caloric will be evolved from the combined state in a given time. Heat being one of the greatest stimuli of animated nature, will further excite arterial action even to the most minute ramifications. Accordingly we find, that iron is "considered one of the most powerful tonics. It increases the force of the heart, acts upon the secreting powers, improves digestion, and invigorates the whole system." (MOORE'S *Mat. Med.*) That iron does enter into the blood by the lacteals, is proved by its being present in a preternatural quantity in the urine of persons who have been under the use of it, and by their blood being of a more florid colour, containing more than a natural quantity of this substance. (MENGHINI quoted by FOURCROY and CHAPTAL.)—This explanation, of the operation of iron, accounts for its good effects in cachexies, and shews how and why it is so effectual in restoring the floridity of the countenance and fresh colour of the whole body.—May not iron be given in conjunction with phosphorus, or the phosphoric acid with advantage?



man calculi become of a florid red, as does also the blood, if oxigene be communicated to them by the nitrous acid. 4. Animal substances receive the red dye better than any other. Probably these two phenomena are not only produced through the intervention of phosphorus, but also of iron, as both are present.\*

A great quantity of phosphoric acid is formed in the animal body. It enters largely into the composition of bone. It exists in a naked state in the gastric juice. It is found in the blood. In fact, it enters as an ingredient in almost all the parts of animal bodies. Large quantities are daily evacuated from the system through the urinary organs, and by the skin.

As oxigene is the great *acidifying* principle through nature, phosphorus can only be brought into the acid state through the intervention of this principle; and as it is impossible to conceive of any other way in which oxigene can have access to the blood but by the lungs, it is evident that this substance must acquire its oxigene directly from the air during the passage of the blood through that viscus, or indirectly from some substance which had previously undergone the

\* Whether these substances are formed in the bodies of animals or not, is not to the present purpose to inquire; it is sufficient to have ascertained that they are never-failing ingredients in red blood. If they are formed in animal and vegetable bodies, they are not simple substances, as they are at present esteemed. The chemistry of nature is not sufficiently attended to. The marine acid radicle, alkali, and probably calcarious earth can be formed in the bodies of animals.

the process of oxygenation there.—There is no substance in the blood from which phosphorus could receive oxygen in this indirect manner except iron. As the attraction of phosphorus for oxygen at the temperature of animal bodies is greater than that of iron, and as they are equally exposed to the influence of this principle in the lungs, the former must necessarily undergo the greatest change.

These considerations induce me to believe that the florid colour of blood is owing to iron and phosphorus, brought into a state of union by oxygen. I am inclined to believe that these substances are united in the blood, because oxygen is the bond of union between *acids* and *metals*, and because the chemistry of art can unite them through the intervention of carbone (pure coal.) Every circumstance favourable to their union exists in the blood, together with the more sublime operations of the chemistry of nature.

The idea then of the process, to which I have been conducted by this course of induction, is simply this. During the passage of the blood through the minute branches of the pulmonary artery oxygen becomes united to phosphorus and forms the phosphoric\* acid. The iron is reduced to the state of red oxide,

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\* Nature appears studious to accomplish this object, by exposing the greatest possible quantity of surface to the oxygenous gas; the area of the air vesicles of the lungs being at least equal to the surface of the whole body.

and partly by a communication from the acid. When these substances have undergone a certain degree of oxygenation, they become united by a further addition of oxygen; probably at the same time some other part of the blood may be combined with them, which, when existing in a perfect state of union, constitute the colouring of the blood. During this union, which not only takes place in the blood while in the lungs, but also in other parts of the arterial system, carbon is disengaged; and when the blood is undergoing a change from arterial to venal, it unites with oxygen, and is exhaled from the lungs and surface\* of the body in the form of carbonic acid. From this view of the subject I maintain that some of the immediate principles of the blood become the base of its colouring part.—Are the laws of the chemical attractions modified by the living principle in this function, or is it, like digestion, a pure chemical process?

This theory, which appears to me to be supported by a number of facts and strong analogies, is sufficient to explain all the phenomena connected with respiration. The affinity of phosphorus for oxygen, accounts for the rapid decomposition of oxygenous gas in the lungs; the union of phosphorus and iron, for the colour of the blood. It shews how blood is changed from venal to arterial, and from arterial to venal. It explains why the blood becomes more red when exposed to oxygenous gas, although covered

\* See Note page 12.

ed with a stratum of serum of the thickness of two inches and an half; and why this change cannot take place when it has even the slightest covering of saliva, oil, or water. It shews why azotic and hydrogenous gases are unsusceptible of decomposition in the lungs. And it may serve, in some measure, to throw light on the deleterious operation of carbonic acid in the lungs. The different temperatures of animals, and the different degrees of floridity in their blood, are likewise explicable in a degree by this theory. It not only affords a satisfactory explanation of the formation of phosphoric acid in the blood, but also explains the spontaneous combustion of animal bodies, and may, in some measure, elucidate the gout and stone.

*Oxigene*, deprived of that principle which maintained it in the gaseous state, and having assumed the solid form, carries almost all its caloric with it. The state in which oxigene exists in the air, is that of elastic fluidity. It is capable in this condition of having its bulk increased like all other substances in nature, by the addition of caloric. But, when deprived of that portion of caloric which overbalanced the attractive power between its particles, and maintained it in the aeriform state, it assumes the solid form: in this condition it exists in the oxides of metals, concrete acids, &c. On account of its strong tendency to combination it has never been obtained in a separate state, or there is no doubt, but that, like other bodies, it might be brought into the intermediate state of elastic fluidity  
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and solidity. This may yet be effected by the conjoint action of cold and pressure. In water and many of the acids, oxigene approaches nearly to this condition; in the former, its proportion is as eighty-five to fifteen of hydrogene.

LAVOISIER, when on the subject of ascertaining the quantity of caloric disengaged during different species of combustion, makes it an important desideratum in chemistry, to find a method for determining the quantity of caloric which oxigene takes with it when it assumes the solid form. He supposes, that the oxigene entering into the composition of the oxygenated nitric and muriatic acids, takes caloric with it; hence (says he) “ the violent and dangerous deflagrations which the neutral salts, in which these acids enter as components, produce with charcoal and many metallic substances.”

The violent explosion of the *aurum* and *argentum fulminans*, can only be explained upon this principle. Amoniac (volatile alkali) is requisite to the formation of both, which is itself proved to be composed of the bases of hydrogenous and azotic gases (hydrogene and azote.) From the analogy of these elementary substances with oxigene, it is presumeable that they likewise take caloric with them when they assume the solid form. The caloric thus existing in the solid form in the ammoniac, and also in the oxigene of the oxide of the metal, being rapidly disengaged by the formation of new combinations, is sufficient to account for all the appearances which these substances

substances present. Analogous to the fulminating gold and silver are gun-powder and the common pulvus fulminans, which explode equally well in vacuo as in open air.—During the explosion of fulminating gold and silver, which will take place in copper tubes, water and azotic gas are produced: the products, after the explosion of the pulvus fulminans, and gun-powder, are entirely gaseous.—How can the production of these various fluid substances from solids be explained, unless it is allowed that caloric, under certain circumstances, can take the solid form; and that the same caloric, in consequence of an alteration taking place in the substance by which it is held in chemical union, shall assume another state, and be the cause of liquidity and elastic fluidity?

Caloric is, no doubt, in a degree condensed in the natural state of the air; for if thin glass bubbles, filled with air, be placed under the receiver of an air-pump, they will burst; bladders, partly filled with air, under similar circumstances, immediately swell—the latter fact takes place with bladders partly filled with air when taken to the tops of high mountains. Mr. BOYLE found air to expand in vacuo one hundred and fifty times; but this falls vastly short of the bulk which it is capable of occupying.

It is impossible to limit the bounds of the condensation of air. BOYLE made it thirteen times more dense than it was before he applied the pressure.

HALLEY

HALLEY says that he has seen it compressed into one-sixtieth of its natural space. HALES condensed it thirty-eight times. It has been lately made to occupy one hundred and twenty-eighth part of its former bulk.

It is evident, that in the condensation of air, caloric is not squeezed out, for it instantaneously returns to its former condition when the condensing power is removed, as may be seen in the familiar instance of the air-gun. It would not only return to its former volume, but would actually pass infinitely beyond it, was it not for the mechanical pressure of the contiguous atmospherical column. If in the compression of air caloric was forced from between its solid particles, it would be in a free or disengaged state, and consequently would manifest itself by heat.

In the expansion or condensation of air there is neither an addition nor diminution of caloric, there cannot be of the solid matter, caloric can then be made to occupy a greater or lesser space than it naturally does in air; its particles cannot be in contact even in the most condensed state of air. If caloric is matter, and if it be subject to the laws of the chemical attractions, and can exist in bodies not only as water does in a sponge, but also in combination; why may it not become part of their solid substance?

From what has been advanced above, it appears that oxygenous gas is decomposed in the lungs. That its solid matter, oxigene, becomes the floridifying  
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ing principle of the blood, and that iron and phosphorus are the substances capable of being floridified. It was then rendered probable from the nature of fluid and solid, and from several phænomena explicable upon no other principles, that the bases of gases when assuming the solid form carry caloric with them.

I now think it probable, that the caloric thus united with the oxigene\* in the blood, is evolved in the extreme arteries, and is the greatest source of heat to animal bodies.

In maintaining an opinion that heat is not communicated to animals by the blood from the lungs, but that it is evolved in every point of the body which contains arteries, I know that I shall act in opposition to the sentiments of great names—*Amicus* PLATO *sed amica veritas magis*.

Although we do not know in what manner arteries evolve combined caloric into the free or sensible state, yet that its evolution is connected with the action of the arterial system is an obvious truth. But whether this depends upon the action of the arteries, or upon that cause by which arterial action is directly produced, will be difficult to determine.

\* “One hundred parts of phosphorus require one hundred and fifty-four parts of oxigene for saturation.” It has been already observed, that the proportion of oxigene in the red oxide of iron is as thirty-four to one hundred. If one hundred and thirty grains of oxigene are combined with the blood in one hour, three thousand one hundred and twenty must be fixed in the course of one day, which appears to me to carry combined caloric sufficient to be adequate to the effect of the heat of the human body.

mine. We certainly know, that arteries possess the power of decomposing the blood, and of recombining it again, as in the various secretory organs of the system. Analogous to this, is that change which the blood undergoes from arterial to venal, as it passes through the extreme arteries into their anastomosing veins. As the affinities of bodies for caloric, and capacity for containing it, are changed when they undergo any chemical alteration, it is easy to conceive that blood, when it undergoes the change just mentioned, shall throw out a quantity of its combined caloric, which will manifest itself in the sensible form. During this change of blood from red to black, disengaged oxigene may unite to its carbone, and form the carbonic acid which is exhaled in such quantities from the lungs and skin.—The blood being deprived of its oxigene, by its union with carbone, by a quantity of phosphoric acid going to the formation of bones and other purposes, and by a portion of this acid constantly passing off by the kidneys and skin; the system at the same time continually generating phosphorus; it is again prepared to attract oxigene in the lungs, and thus is kept up the perpetual round of changes in the blood from venal to arterial, and from arterial to venal during the existence of animals.

The idea of animal heat, which is deduced from the theory of respiration already given, is simply this. By the decomposition of oxigenous gas in the lungs, a quantity of oxigene is communicated to the  
blood.

blood. The oxigene thus combined carries a large portion of its caloric with it; which is gradually evolving by the oxigene forming new combinations during the circulation, and which becomes more completely evolved in the extreme arteries by that power which changes blood from arterial to venal.

This idea of animal heat rests on the following observations, and its easy application to the explanation of phænomena. The heat of animals is in proportion to the extent, perfection, and vigour of their lungs: thus birds are warmer than terrene animals; these latter are warmer than the amphibious, and these still more so than fishes, whose temperature is scarcely above that of the element in which they live. Animals appear to destroy oxigenous gas in proportion to their temperatures. The blood of animals is found to correspond with their lungs; that of land animals containing a greater quantity of crassamentum, and being more florid than those which live both on land and in water, and these latter again more so than fishes, whose blood is pale, aqueous, and in small quantity. The state of the blood does not only differ in the different classes and species of animals, but also in individuals of the same species: “in infants, delicate women, and weakly men, it is paler, and less disposed to coagulate, than in robust healthy persons. The blood is thin and pale coloured in cachexies, but in diseases of an opposite diathesis it is highly florid, and contains a large proportion of crassamentum, corresponding with the weakness or  
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strength of the pulse. Any cause increasing the energy and action of the arteries, increases heat. Every part of the body containing arteries, is susceptible of inflammation,\* or an increased generation of heat, even the *vasa vasorum* of the lymphatics; and that in proportion to vascularity and sensibility. Inflammations are generally circumscribed, which would not be the case if heat was communicated through the body by a mere diffusion from the lungs. Every part of the body is capable, in a certain degree, of supplying itself with heat, according to its exigencies. Children have been born with marks of the small-pox, the suppuratory process of which disease implies inflammation.

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\* Inflammation is confined to the extreme arteries. The phenomena of this disease all concur in showing that there is an increased impetus of the blood in the vessels of the part affected; and, as at the same time the action of the heart is not evidently increased, this is sufficient reason to conclude that the increase of heat in the part is owing to an increased action of the vessels independent of the heart. An increase of action in any set of vessels produces preternatural heat. Active inflammation may therefore be defined **AN AUGMENTATION OF THAT POWER BY WHICH CALORIC IS EVOLVED FROM THE COMBINED TO THE FREE STATE.** A topical accumulation of excitability or stimulability will render the vessels of that particular part more susceptible of the action of the oxygenated blood, by which means their action will be increased (not their energy), and consequently a greater quantity of blood will circulate through the part in a given time than in health, and by this means a greater quantity of heat be evolved. Inflammation may thus continue by the part generating its own stimulus, till nature relieves the vessels by resolution or suppuration: but if the excitement of the part be raised too high by the stimulant operation of heat, that principle upon which the stimulus acts will be worn out; the part being thus deprived of that principle, which, when present, modified the agency of septic powers, it will consequently be left to the destructive action of external agents, decomposition will ensue, and the components of the skin, muscular fibres, &c. form binary combinations, which constitutes sphacelus.—Upon this principle of a part generating its own heat, the continuance of inflammation can be accounted for, without supposing a spasm to exist in the extreme ends of arteries to support their action, or without recurring to a **VIS MEDICATRIX** for its formation.

If the heat of animal bodies was all evolved in their lungs, the following propositions would be found to be just. 1. The parts of the animal body would be cool according to their distance from this supposed centre; for it is an established law in Nature, that heat shall decrease as it recedes from the source from which it originated. 2. No part would be susceptible of an increased degree of heat. 3. No part could resist the topical application of cold. 4. The *fœtus in utero* would generate no heat, and consequently would be unsusceptible of inflammation. The accurate observer of the phænomena of animal bodies will perceive that the reverse of these is the fact,

If the animal body had not the power of preserving itself nearly at one uniform temperature, it would be impossible for it to exist. Heat is an agent which regulates chemical attractions: if the body was raised much above, or sunk much below its natural standard, the chemical operations which it performs would be varied, new combinations formed, and death ensue. It was, therefore, necessary that the temperature of animal bodies should be nearly equal, whether they were exposed to the cold of Siberia, or to the burning heat of the torrid zone,

To support this regularity, Nature has made abundant provision. In the frozen regions of the earth, and during cold seasons of the year, atmospheric air contains a greater quantity of oxygenous  
gas



gas under a given volume, than it does in warm climates and seasons; and, according to the idea, p. 30, a greater quantity of caloric is contained in condensed than in rarefied air, and most certainly more oxigene. Under these circumstances a greater quantity of oxigenous gas will be decomposed in the lungs, in a given time, than in warm climates and seasons, and consequently a greater quantity of oxigene fixed in the blood. If this fluid is stimulant to the sanguiferous system in proportion to its degree of oxigenation, the animal system will be able to preserve one uniform temperature, whether it be exposed to an atmosphere at the freezing point of mercury or at the boiling point of water.\* When the atmosphere is cold, and consequently the animal body deprived of a great quantity of heat by its mechanical contact, the air is most replete with oxigene and caloric, which are the great causes of animal heat. The contrary takes place when animals are surrounded by a warm atmosphere.

According to my arrangement of this subject, I have only to mention the effect of respiration on the action of the heart. The connection between the state of the breathing and the pulse has been noted by BOERHAAVE, HALLER, ZIMMERMAN, M<sup>r</sup>BRIDE, GREGORY, and every other writer on physiology and pathology.

\* It is a well known fact, that the human body is not colder in the northern regions, where mercury has been known to freeze; and the experiments of BLAGDEN and FORDYCE shew that its temperature is not much increased when exposed to air where FARENHEIT's Thermometer stood above two hundred and forty degrees.

pathology. This natural connection between these two vital functions has been brought to account for the success of HIPPOCRATES in curing diseases; who, it is said, almost neglected the pulse, but attended particularly to the state of the breathing.

GOODWYN supposes that the heart is indebted only to the chemical change which the blood undergoes in the lungs for the support of its incessant action. He therefore denies that the dilatation of the thorax is the final cause of respiration; and asserts that the circulation of the blood through the lungs, even in the most perfect state of expiration, is sufficient to support the life and health of animals. The death of animals by drowning and strangulation, he supposes to be owing to venal blood passing from the right to the left ventricle of the heart unchanged.

HALES and HALLER suppose that the dilatation of the lungs is necessary to the free transmission of blood through them. The former of these authors goes so far as to suppose that this is the only use of respiration.

It appears to me that the truth (as usual) lies between these two extremes: the blood not only appearing to stimulate the heart in consequence of being oxygenated in the lungs, but also by mechanically distending it.

If the conclusion of GOODWYN was founded in Nature, would there be that intimate connection between

tween the frequency and force of the heart's action and the frequency and fullness of respiration? Would the suspension of respiration produce that turgescence and redness of the face which it is invariably found to do? From HALE'S account of his experiments on dogs, it appears that the circulation of the blood was supported in a kind of mechanical manner, by forcibly distending the lungs with air, which must have been much vitiated by its having been frequently taken into the lungs of the animal. CULLEN observes, that "the tone of the arterial system depends upon its tension." I know of no reason why this will not apply to the heart in some measure. The right or anterior ventricle of the heart acts without the stimulus of arterial or oxygenated blood. This GOODWYN says is because the venal blood is its proper stimulus. Does it not act by the stimulus of oxygenated blood in the foetus state?—According to GOODWYN'S idea, a different organization is implied in the ventricles of the heart, to render each susceptible of its peculiar stimulus, which is not proved.

Upon the whole, I am induced to conclude, that the uninterrupted action of the heart is owing to the evolution of caloric from the oxigene of the blood as it passes from the lungs to the heart, to the oxigene which changes the blood from venal to arterial, and to the mechanical action of the blood.

Is the tenacity of the hearts of animals, for their vis insita or irritability, increased in proportion to the diminution of the power of their respiratory organs in decomposing oxygenous gas?—and do their temperatures decrease in the same ratio?

From the doubts, difficulties, and uncertainties which occur in attempting to explain the phænomena of respiration (and indeed of almost every other function of the animal œconomy) I am convinced that much more is still to be done. There are not yet a sufficient number of facts collected, and experiments made, to constitute the basis, or serve as data for reasoning in a satisfactory manner; I have no doubt, and I have analogy in my favour, that this will soon be done. A genuine spirit of investigation prevails—Revolutions are taking place in every species of knowledge—MEDICINE does not remain stationary; and from the unbounded prospects which chemistry opens to view, I have no doubt but that a period is commencing which will mark a glorious æra in the history of this science.

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